SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATE FIELD STUDIES EDUCATION

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There is an ever-increasing number of issues that face our world today; from climate change, water and food scarcity, to pollution and resource extraction. Science and ecology play fundamental roles in these problems, and yet the understanding of these fields is limited in our society (Miller, 2002; McBride, Brewer, Berkowitz, and Borrie, 2013). Across the nation students are finishing their undergraduate degrees and are expected to enter the workforce and society with the skills needed to succeed. The deficit of science and ecological literacy in these students has been recognized and a call for reform begun (D’Avanzo, 2003 and NRC, 2009). This mixed-methods study looked at how a field studies course could fill the gap of science and ecological literacy in undergraduates. Using grounded theory, five key themes were data-derived; definitions, systems thinking, human’s role in the environment, impetus for change and transference. These themes where then triangulated for validity and reliability through qualitative and quantitative assessments. A sixth theme was also identified, the learning environment. Due to limited data to support this themes’ development and reliability it is discussed in Chapter 5 to provide recommendations for further research. Key findings show that this field studies program influenced students’ science and ecological literacy through educational theory and practice.

Keywords: grounded theory, mixed-methods, triangulation, science literacy, ecological literacy, undergraduate education, field studies, educational theory
SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATE FIELD STUDIES

EDUCATION

By

Kim J. Mapp

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Chapter 1 Introduction

Throughout the world, communities, states and nations face drought, climate change, food scarcity, pollution, resource extraction and loss of biodiversity, to name a few (Miller, 2002; NRC, 2009). These ever-increasing challenges are likely to grow in strength before they are fully addressed and steps are made to solve them.

At the turn of the 21st century only twenty percent of the adult population in the United States were considered scientifically literate (Miller, 2002). These results are shocking, despite the ever-increasing reliance on science and technology in our everyday lives. The populaces’ misconceptions and gap in general understanding of scientific processes perpetuates such problems.

The scientific discipline of ecology underpins many of the issues of the 21st century and continues to bring forth new understandings and data that help us interpret and engage in the complexity of our world. Unfortunately, there are still general misunderstandings of ecology as an activist movement instead of a scientifically sound body of work (Jordan, Singer, Vaughan, and Berkowitz, 2009). Solving large environmental challenges requires an understanding of the interconnectedness of our environment and humans’ role within such (Jordan et al., 2009).

Current undergraduate and graduate students across the United States are seen as the generation to address the ever-growing problems facing our world. For these students, having a level of scientific and ecological literacy is essential for understanding and potentially catalyzing change in these issues. A call to action has been recognized with the challenge to fundamentally change the post-secondary educational system in science and ecology (AAAS, 2011; NRC, 2009; Gardner et al., 1983).
Field studies education has the potential of answering this call of educational reform in the sciences. This may be accomplished by reaching a wide range of students, being interdisciplinary and based in the pedagogical practices, while providing opportunities for students to gain science and ecological literacy skills.

**Statement of the Research Problem and Purpose**

The purpose and mission of higher education is to prepare its students for being active and productive members of society. Scientific and ecological literacy, as well as, critical problem solving skills are essential for all members of society given the challenges we face. It is clear that students are not gaining these skills during their time in college.

The purpose of this study is to highlight the ability of field studies programs to answer this call for educational reform in the sciences. Field studies education has the potential of providing required skills, as well as, interdisciplinary and theory based practice for science and ecology education.

**Research Question**

In what ways does a field studies course (Rocky Mountain Field Ecology) influence ecological and science literacy in undergraduate students?

**Key Terms Defined**

There are three key terms that are essential to this research including, ecological literacy, science literacy and field studies education. Each of these topics will be briefly defined while the historical context and full review of each subject will follow in the literature review section.

Ecological literacy is defined by McBride (2013) as simply, “the knowledge necessary for informed decision making, acquired through scientific inquiry and systems thinking” (p.3).
Systems’ thinking is the foundation of ecology which studies the complex relationship of biotic and abiotic elements in varying scales of time and space.

Science literacy considers not one type of science, but all. In 2002 Jon Miller coined the term “civic scientific literacy” and stated that there are three elements that are composed in this;

1. an understanding of basic scientific concepts and constructs, such as a molecule, DNA, and the structure of the solar system,
2. an understanding of the nature and process of scientific inquiry and
3. a pattern of regular information consumption. (p.4)

These elements, Miller believed, were for the general public, not just academics or college students (2002).

Field studies education can most closely be defined through the merging of constructivist theories and place-based education. Constructivist theory is the idea that students are active participants of their knowledge acquisition, through dialogue, collaborative work, inquiry and manipulating materials (Ishii, 2003). Place-based education is rooted in teaching through a local lens; where students are engaged in hands-on experiences, using the community as a teaching tool (Ishii, 2003; Semken and Freeman, 2008). Most simply put, field studies education is teaching and learning that happens beyond the walls of a classroom. Where students are immersed in the topic, are intimately connected to their learning and the educator’s role is that of a guide towards understanding (Brackney, 2008).

**Summary**

Increasing environmental problems and the integration of science and technology in our everyday lives has created and impetus for reform in undergraduate education. Field studies education has the potential of recognizing this call due to its foundation in educational theory.
This research intends to examine how science and ecological literacy is influenced through these types of programs.
Chapter 2 Literature Review

Introduction

This literature review and the following study will impart a synthesis of the status of field studies education, ecological literacy and science literacy. In doing so, holes will be identified in the primary literature and ways in which to extend research on these topics will be explored.

Science Literacy

Science literacy has evolved in the public’s eye and the educational system through time. Prior to the 20th century the role of science education differed in importance and value. T.H. Huxley reflected on his discontent of teaching science in saying that it was “speculative rubbish” and “the scientific habitat of mind is an impediment… in the conduct of ordinary affairs” (as cited in Anelli, 2011, p. 235). Yet during the same century an explosion of sciences occurred with explorers such as Darwin and Lewis and Clark, chemists like Marie Curie, or botanists and naturalists like George Stellar and John James Audubon. Yet for the most part science was still not an explicit part of the educational system.

John Dewey (1859-1952), an American reformist in education, pedagogy and psychology, recognized this lack of science in the educational system and called for,

Influencing a much larger number to adopt into the very make-up of their minds those attitudes of open-mindedness, intellectual integrity, observation and interest in testing their opinions and beliefs that are characteristic of the scientific attitude. (1934, p.3)

Even with this call for reform and greater access, it wasn’t until the era of Sputnik and the space race that the general public took notice of science and its role in daily life (Anelli, 2011; Laugksch, 2000). During this period the population began wrestling with the details of space travel, while the government called for an increase in science education and Science,
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Technology, Engineering and Mathematics (STEM) careers (Anelli, 2011; National Research Council (NRC), 1996).

Since the Sputnik era two major publications became seminal in calling for a reform in science education, *A Nation at Risk* (Gardner et al., 1983), and the *New Biology for the 21st Century* (NRC, 2009). *A Nation at Risk* was a publication from the National Commission on Excellence in Education, as a statement of where the United States’ education system stood; it defined problems, and gave practical ideas for improvements. The view of the report, and that of the nation in the early 80’s, is clearly stated in their opening line,

Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science and technological innovation is being overtaken by competitors throughout the world…the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and people. (1983, p.5)

This report was the first of its kind, and the first call for a reform in our science education system. It documented the steady decline in many student achievements such as SAT scores, higher order thinking, and science achievement scores. The authors recognized that, as the global economy and technology boomed, students in America were less-prepared and less-educated as a whole than were their parents. They called for an unequivocal stance as a nation to create change at every level of education, to meet the high standards and commitment of other developed countries, and reform in content areas. This led to the initial development of science standards.

Nearly a quarter century later the National Research Council responded with the *New Biology for the 21st Century* (2009), recognizing the state of science literacy in the nation and called for reform once again; this time in-light of even greater technological advancements and
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everyday integration of science and technology in our lives. The authors were charged with answering the question “How can a fundamental understanding of living systems reduce uncertainty about the future of life on earth, improve human health and welfare, and lead to wise stewardship of the planet” (NRC, 2009, p. vii)? This committee sought out research efforts of science, and specifically biology, for integration into other research sectors such as math, engineering, physics, and chemistry, to solve complex inter-disciplinary problems. One of the four recommendations that the report made was the creation of “interdisciplinary curricula, graduate training programs, and educator training for New Biologists” (NRC, 2009, p. 89). This publication, its 1983 counterpart, and the peer-reviewed articles on science literacy provide a framework for science literacy’s importance.

But what does it mean in the context of undergraduate education and the focus of this research? The NRC (2009) report states that students who are scientifically literate are able to understand the core concepts of (1) Evolution; (2) Pathways and transformations of energy and matter; (3) Information flow, exchange, and storage; (4) Structure and function; and (5) Systems. These five things are deemed “threshold concepts” in which students must be able to understand and ultimately master to progress from novice to experts in the field (Ross et al., 2010). For undergraduate students (both science majors and non-majors) the progression of learning must begin at first mastering these threshold concepts, before conducting their own research or taking upper level biology, chemistry or ecology courses. It is also at this point where many students become frustrated with the subject, being unable to move past the initial content area (Ross et al., 2010). Therefore, undergraduate science courses must recognize these concepts and be able to fully support each student in their progression through and past the threshold if there is to be successful student science literacy.
Two definitions of scientific literacy were used for this research. First, the National Research Council (NRC) defined science literacy as the ability to “use evidence and data to evaluate the quality of science information and arguments put forth by scientists and the media” (as quoted by Gormally, Brickman, and Lutz, 2012, p. 364; NRC, 1996). The Programme for International Student Assessment defines science literacy as, “the capacity to use scientific knowledge to identify questions and draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (as quoted by Gromally et al., 2012, p. 364; Organisation for Economic Co-operation and Development, 2003). Through both of these definitions it is evident that the essence of scientific literacy means knowing where to get proper information and how to understand it once you have it. These same definitions were used in creating the Test of Scientific Literacy Skills (TOSLS), which was used for this project (Gromally et al., 2012).

**Ecological Literacy**

The history of ecology stems from early studies of natural history, dating back to the Greeks and more recently, Charles Darwin and Carl Linneaus (Egerton, 2012). Carl Linneaus (1707-1778) is believed to be the first person to coin the formal science of ecology, as the “economy of science,” in which his work in systems and taxonomy would be later used by Charles Darwin (Egerton, 2012, p.80). Since this time ecology has transformed and evolved into different sectors, including community, population, and landscape studies. It can be defined as a section of biology that studies the relationship of “living organisms and their interaction with their environments” (Subrahmanym and Sambamurty, 2007, p.1.1).

At the turn of the 21st century there was an explosion of literature on ecological literacy and its integration into undergraduate education. Jordan et al. (2009) summarizes a handful of
these ecological literacy frameworks (see Table 1) while showing a progression of academic understanding of the field. In this table are ideas and definitions that later would be considered either ecoliteracy or environmental literacy instead of ecological literacy (McBride, 2013). For the purpose of this study McBride et al.’s (2013) definition of ecological literacy will be used; they state that ecological literacy “focuses on the key ecological knowledge necessary for informed decision-making, acquired through scientific inquiry and systems thinking” (p.3).

Table 1

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<th>Frameworks of Ecological literacy</th>
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<td>1. Ecological identity: an integration of content, process, and reflection (Thomashow, 1995)</td>
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<tr>
<td>2. Place and Personal action combined with basic ecological knowledge (Orr, 1992)</td>
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<tr>
<td>3. An interconnected perspective, in which networks are understood at several levels: biological, cognitive and social (Capra, 2002)</td>
</tr>
<tr>
<td>4. Ecological thinking and understanding of key systems occurring in a social context (Berkowitz et al., 2005)</td>
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<td>5. Environmental justice, self-reliance and reduction of consumerism, concern for future generations (Bowers, 2001)</td>
</tr>
<tr>
<td>7. Systems thinking and an affinity for the natural world (Woolpert, 2004)</td>
</tr>
<tr>
<td>8. Place-based sustainability pedagogy, with a focus on relationships and a shifted scientific view of the world (Wooltorton, 2006)</td>
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Source: Jordan et al., 2009.
Notes: A summary of the published literature on ecological literacy frameworks at the time.

With varying definitions and frameworks of ecological literacy, it is challenging to pinpoint what ecological literacy means in the context of undergraduate education. Fortunately, with the calls for reform in 1983 and 2009, multiple authors have closely examined ecology at the college level. D’Avanzo (2003) articulates that the educator as well as the student must drive ecological literacy at higher levels. Unfortunately, traditional introductory biology courses at four-year universities are possibly the only time students will be exposed to the field of ecology. Therefore there should be an increase in ecological literacy during these courses, yet this may not be the case (Cheruvelil, and Ye, 2012). Often in these courses students are given a heavy
workload to understand all the major topics of biology, of which ecology is just one section. Adequately covering ecological concepts in these courses is challenging as Jordan et al. (2009) explain that there are eight key ecological concepts (or threshold concepts as mentioned above) that students must understand:

1. Ecology is a scientific discipline;
2. There are functional connections within species and between species and the environment, and these are not of equal importance when considering specific ecological events;
3. Biotic and abiotic factors interact to influence species distribution;
4. Ecological processes operate to different extents when studied at different spatial and temporal scales;
5. Ecological models are used as descriptors and predictors of ecological processes;
6. Evolutionary theory is the framework for understanding ecological connections;
7. Ecologists interpret ecological processes in context of their own cultural background, and
8. Ecological literacy allows people to understand connections between themselves and ecological processes and can help them make informed decisions about environmental issues. (p. 497-498)

Moving students beyond the novice level in the subject of ecology is a challenge if ecology is taught as just one section of a broader introductory biology class. Hence, students will likely graduate without a higher level of ecological literacy (Cheruvelil et al., 2012).
Field Studies Education:

Field studies education and field research projects are seen as the capstone or culmination for undergraduate students in their specific discipline. These types of programs are seen as informal educational settings closely united with a student’s formal education that extends their learning and makes a subject come to life (Brackney, 2008). A definition of field studies education is illusive in the literature. Yet, mixtures of place-based education (PBE) and constructivist theory have been alluded to in field studies research publications.

Place-based education provides the background for the experiential aspect of field studies. PBE gained leverage in Last Child in the Woods (Louv, 2008) and Beyond Ecophobia (Sobel, 1999) in which there was widespread recognition of students losing their connection to their communities and the natural landscapes around them. Therefore, PBE physically immerses students in the subject matter, roots them in what is happening around them and provides them with experiences to enhance their learning. PBE teachers take their students outside to learn about the local or regional characteristics of their place, encourage interdisciplinary pedagogy, and look to involve the community either by engaging in service work, solving local issues and/or bringing in local experts (Semken and Freeman, 2008). Originally, PBE was easily applied to the sciences and especially natural science, where students are able to engage in the subject matter through outside, hands-on, and interdisciplinary work (Semken and Freeman, 2008; Smith and Sobel, 2010).

In addition to being based in PBE pedagogy, field studies education can also be linked to constructivist theory. Constructivist theory has many branches depending on the theoretical framework, yet Jean Piaget (1896-1980) is considered the father of the philosophy. This theory is generally understood as a way knowing, where students build their own understandings about an
idea or subject through hands-on experiences and prior knowledge (Ishii, 2003). This type of education typically uses primary sources or material that students can easily interact with and manipulate; it is driven by students’ curiosity and responses to a subject, and students are encouraged to engage with each other through discussions or collaborative projects (Ishii, 2003). Social constructivism, as explained by Lev Vygotsky, further emphasizes the role of community in education and he explains that learning occurs within social interactions and stresses the collaborative nature of education (Vygotsky, 1978).

Through place-based education and constructivist theory, field studies education can start to be aligned with collaborative and inquiry based experiential education. This is seen in recent publications where authors have reflected on their own teaching experiences in the field. These educators state an increased connection between students, the subject and the location, as well as students’ heightened interest in thoughtful discussions, asking critical questions and the longevity of the experience on the rest of their educational careers (Greengrove and Secord, 2003; Brackney, 2008; and Eves, Davis, Brown, and Lamberts, 2007).

Faculty members and researchers of field studies education use similar terms to those of place-based education or constructivist theory without clearly defining field studies or its relationship to these (Greengrove et al., (2003); Brackney, (2008); Eves et al., 2007). It is beyond the scope of this project to analyze the overlap and significant differences between field studies, place-based education and constructivist theory.

Summary

Ecological literacy, science literacy and field studies education are relevant and important in today’s educational system and must continue to be valued by society. Key findings from previous literature include:
(1) Science and ecological literacy research allude to the value and need for effective field studies education, through undergraduate instruction being driven by interdisciplinary, collaborative, critical thinking and inquiry based philosophies (NRC, 2009).

(2) Students must understand that science is intertwined into many aspects of life instead of a silo of lab research (NRC, 2009).

(3) Education needs to provide students with the realization that science is a part of their lives and that they are constantly interacting with scientific ideas (NRC, 2009).

(4) Ecology must be taught in a way that prepares students to use the concepts and ideas of the subject beyond a university setting (Jordan et al., 2009).

(5) Previous research and reports in science and ecology have called for new ways of teaching these subjects.

(6) There is a significant gap in the research that illustrates how field studies education is able to influence science and ecological literacy in undergraduate students.

This research identifies the intersection of these three areas, where the proposed reforms of science and ecology education are realized through field studies education.
Chapter 3 Methods

Field Course Design

The field course that was used in this study was based in the Rocky Mountain West in an ecologically diverse and rich ecosystem. This field-based college program has been running consecutively for 4 years while the parent organization has been operating field-based science education programs in the same region for nearly fifty years. This parent organization housed the students and instructors while on course and the educational framework for the course was strongly influenced in the tradition of this program.

The first two weeks of the three-week course were content heavy while the third week consisted of a student driven collaborative research project. During the second week students were camping, while the rest of their time was spent in a rural research station site. The primary focus of the course was ecology in which students were exposed to many levels of ecological thinking including species adaptions, disturbances, ecosystem scales, abiotic and biotic forces, and social ecological systems to name a few. This was accomplished through learning how to read scientific papers, field based lessons, class discussions, exposure to experts and researchers in the region, and immersion into ecologically rich ecosystems where students could get hands-on experience with the subject matter. Other key instructional strategies included species identification, journaling, and large student driven research projects, and readings from ecological thinkers such as Aldo Leopold (see Appendix B for syllabus).

Research Participants

The participants of this study were 15 traditional undergraduate students from a small private liberal arts school based in Southeastern United States. In total there were 5 females and
10 males. Two of the male students selected to leave after the second week before the group research project, by choosing to take the two-credit option instead of the full four-credit course.

All of the students were self-selected for this study through registering and participating in the field course. Due to the self-selection process there was no control of gender, age or student’s major. Due to the nature of the program, demographics of the school and requirements for graduation, the research team expected to see a diversity of majors and class-standings. Participants were fairly split between non-science majors (53%) and science majors, including environmental studies (47%) as well as class standing: Sophomore (20%), Junior (53%), and Senior (27%). Ethnicity demographics were not taken on the students. Students volunteered to participate in the study and were given equal notice and information pertaining to the extent of the study and their role within it. At any point they could elect to not be a part of the study with no repercussion to their grades. Similarly, there was no reward or compensation given to the students who elected to be a part of the study.

Due to the use of human subjects, two IRB’s were issued, one from the college that the students were a part of and a second from the university where the primary researcher was based. As part of the IRB, participants’ identities were to remain confidential. Students coded their pre and posttests with a unique number they would remember. This number was not given to the research team. In addition, the primary researcher assigned pseudonyms when she was able to identify who was speaking during class discussions or in written artifacts.

Materials: Instruments

The materials for this study included audio-recorded class discussions, pre and posttests and transference papers.
Audio recordings of class discussions were completed each week of the course, and in total there were 5 hours of recordings broken into four different class discussions (one in week one, one in week two and two in week three).

The pre and posttests were comprised of three sections: Likert-type scale questions (20 questions), Test on Scientific Literacy Skills (TOSLS) (7 questions), and open-ended essay style questions (5 questions) (see Appendix A for full pre and posttest). The Likert-type scale had questions centered on the purpose and importance of science and ecology in society and students’ personal lives.

Gromally et al. (2012) created the TOSLS tool to help university level science educators to assess their effectiveness in educating key science concepts. Seven questions were pulled directly from this test and used in the pre and posttest. Finally, the open-ended essay questions were formatted to provide students with an opportunity to expand upon previous questions pertaining to science and ecology in their own life as well as more complicated scientific and ecological ideas. The research team, who are experts in the field of science and ecology, wrote the five questions used for this as well as the Likert-type scale questions.

Transference papers were used in the final stage of analysis in this study. These papers were written after the class ended and prompted students to connect their field experience to something of significance to them back home (see Appendix B, syllabus, for full description of the project).

**Procedure**

At the beginning of the course, students were asked to participate in a study focused on science and ecological literacy and were given consent forms and specific details regarding their involvement. Students were openly given the option to participate and if they chose to
participate they could terminate their involvement in the study at any point with no repercussion to their grades or status within the course. Students were also informed that there was no compensation for their participation.

Data collection began with a pretest (as described above), which took students less than an hour to complete. The pretest was done before any introductory lessons were taught or exposure to content occurred. Each week audio recordings were taken during class discussions. At the end of the three weeks students were then asked to take the posttest. Transference papers, completed after the conclusion of the class, were the final data source for this research.

**Research design: Grounded theory, triangulation and Bloom’s taxonomy**

This research project had multiple levels and facets in its design. Grounded theory was used as the overarching research method, and as a lens in how to interpret the data, its analysis and ultimately the results. Triangulation of qualitative and quantitative data produced a mixed methods design providing validation and reliability in the data.

Grounded theory is defined as, “a general methodology for developing a theory that is grounded in data systematically gathered and analyzed” (Johnson and Christenson, 2014, p.456; Glaser and Strauss, 1967). Grounded theory methodology provides the researcher with the ability to draw conclusions and findings directly from what happened, providing explanations of events; which can then be expanded to other similar experiences (Corbin and Strauss, 2015). To achieve this, the researcher must go through an iterative and cyclical process of being completely absorbed in the data (Corbin and Strauss, 2015). This type of research is inverted when compared to many other forms of research. A hypothesis was not formed and tested before the analysis but instead the data guided the researcher to significant findings while trying to answer the research question. The power of grounded theory is that it allows the participants or data to
show what actually happened instead of being filtered through one or two testable hypotheses (Corbin and Strauss, 2015). By using a grounded theory approach, the team was able to provide an explanation to what happened during the field course, moving beyond describing the event to providing a ‘why’ to what occurred. Grounded theory also differs from other forms of qualitative research by not stating a theoretical framework before the analysis. Rather, the framework comes out in the discussion where results can be compared to other theories or frameworks (Corbin and Strauss, 2015). For this reason the theoretical framework for this research, Bloom’s taxonomy, will be discussed in detail in the final chapter.

To show validation and reliability in the results, a process of triangulation was used while analyzing the data. Triangulation “refers to the gaining of multiple perspectives through completed studies that have been conducted on the same topic and that directly address each other’s findings” (Richards and Morse, 2007, p.91). In this research the sources of data that help support each other include (1) audio transcriptions (2) pre and posttests and (3) student transference papers. For the results to be triangulated they must converge to one finding or idea, where data are able to “challenge, illuminate or verify” each other (Richards and Morse, 2007, p.91). Each theme originated from coding of the audio transcripts while the two other sources, the tests and papers, were used to triangulate findings depending on their relevance to the theme. These sources are described at the beginning of each theme in the results chapter.

The mixed methods approach in this research relies heavily on qualitative data recorded from class discussions and open-ended questions from the pre and posttests. Audio recordings were transcribed, coded, and categorized, resulting in five major themes. These themes were then member-checked with a member of the research team. This member used the major themes to recode the four audio transcriptions and the pre and posttests’ open-ended questions. Any
overlap that occurred in coding was then established as reliable and valid coding and was used in the results section of this study.

The Likert-type questions were analyzed using a factor analysis to find pairings of questions in which students answered similarly. This provided statistical reference to which questions were most significant, and thereby reduced the data to these points (Taylor, Sinha, and Ghoshal, 2006). A paired sample t-test was then used to determine significance for each question (Bradley et al., 1999). For the TOSLS test, a paired sample t-test was performed on the percent of questions answered correctly in the pretest to the percent of questions answered correctly in the posttest (Gromally et al., 2012).

Finally, quotes from transference papers were analyzed through word queries, using Nvivo software (Nvivo, 2014) to show how students were relating key themes beyond the course. These queries were then expressed visually through quote bubbles, see Chapter 4. All of the data and findings were then discussed through the lens of a theoretical framework to explain the findings, see Chapter 5. See Figure 1 is a visualization of the research process.
Figure 1. Visualization of research methods and process
An integral part of grounded theory is identifying the theoretical framework after the analysis of data (Corbin and Strauss, 2015). Following the identification of the five themes, and triangulating each of them, the researcher was able to draw connections to wider understandings and theories. It was here the correlation to Bloom’s taxonomy (Bloom, Engalhart, Furst, Hill, and Kratwhol, 1956) became apparent.

Taxonomy of Educational Objectives, commonly known as Bloom’s taxonomy, provides a framework for categorizing educational goals, whereby educators are able to assess and scaffold lessons and units to differentiate student’s needs and abilities. Since the original publication (Bloom et al., 1956) there have been a hand-full of revisions and edits to reflect the growing knowledge of child and adult psychology as well as our understanding of educational theory (Krathwohl, 2002; Airasian, Cruikshank, Mayer, Pintrich, Raths, and Wittrock, 2001). In this framework there are six main levels of objectives, with sub-categories in each: knowledge, comprehension, application, analysis, synthesis, and evaluation. Knowledge is the foundational level of Bloom’s taxonomy and seen as a precondition for the top five objectives or “abilities and skills,” to then occur (see Figure 2). For example, after students understand what a food web is, they then diagram one from their local ecosystem. By using this framework the researcher was able to compare and contrast the findings of this project to an established educational theory and help provide an explanation for why each of the results were found. This is explained in detail in Chapter 5.
Grounded theory is the overarching method of analysis used for this research, which provides an opportunity for the researcher to pull results directly from the data. A process of triangulation in the data provided validity and reliability in the results, while both qualitative and quantitative data sources were used. Following the results chapter, findings will be explained in greater depth in correlation to Bloom’s taxonomy to show the significance of educational theory in practice.
Chapter 4 Results

Introduction

Five themes were identified that recognized a progression of students’ intellectual behavior and ability in science and ecology, and are briefly described as follows:

- The first theme, definitions, showed students’ cursory understanding of science and ecology, as a foundational level of being able to describe and use vocabulary in a proper context.
- In the second theme, systems thinking, students’ took their basic understanding of science and ecology and began to see the interconnectedness of ecosystems and their functions.
- In the third theme, human’s role in the environment, students’ began wrestling with their own personal land ethic and what the environment and wild places meant to them.
- The fourth theme, the impetus for change, showed how students’ were conceptualizing large environmental issues and how these should be addressed.
- The fifth theme, transference, explained students’ ability to draw connections of their field experience to their life back home.

These five themes came directly from the data, through a method of grounded theory, where the researcher used the audio transcriptions, pre and posttests and transference papers to guide the results. This chapter will look at each theme in detail, showing where each came from and how they were triangulated.
Theme 1: Definitions

The theme of definitions was established and triangulated through data-derived coding of audio transcripts, pre and posttests, as well as statistical analysis of the TOSLS pre and posttest questions. Initial codes and keywords were used to help arrive at this theme through clumping of terms found in the transcriptions such as processes, dynamic, inductive and deductive, abiotic and biotic and natural processes. Once clumped, the theme definitions emerged as a way to describe how students were explaining science and ecology through class discussions and pre and posttests.

In the pre and posttests students were asked to define ecology and science. In the pretests students articulated science as lab work, making a hypothesis, answering questions, using analytical skills or understanding things around them. In the posttest there were similar general responses, with one dramatic change; students articulated science as a dynamic action and not as a linear process. Science for the students was no longer just people in lab coats, but an everyday process that occurred over and over through questioning, hypothesizing, collecting data and repeating. This depth and cyclical understanding of science is seen in the audio transcriptions.

When asked to describe their understanding of science at the end of the course Ben stated, “Science is definitely, definitely a process and its underlying…a lot of other fields and just pretty much involved in everything.” Similarly, Tom explains his understanding of science by saying, “That it’s dynamic, that it’s changing and it constantly changes….You know, so there is more to it than just memorizing certain things and replicating that. There is going out and experimenting and asking questions, and trying to get answers.” Tom and Ben’s responses were just one slice of a larger class discussion in which the class as a whole described a transition of their understanding of science from only lab coats, and set experiments to an everyday dynamic
process. Coding of these class discussions and pre and posttests were the first two phases of triangulation for the theme of definitions.

In the pretest students’ defined ecology as the study of ecosystems, landscapes, animals or plants. In the posttest, across the board, students stated that ecology was the study of the interactions between abiotic and biotic forces. By using these specific terms students were then able to give more complex answers, answers that reflected their scientific understanding of the subject. No longer was it just an ecosystem that students saw but trophic cascades of energy, the relationships of apex predators on the rest of the system and the small, yet distinct differences, that allowed one community to thrive next to another. This depth of understanding in the definitions comes through in class discussions, where in one, Travis states,

I’d known what ecology meant on paper. But getting to come out and look at the different tree communities and realize that there’s a 100 different reasons why there are different tree communities kinda brought it more than textbook could of for me. So I knew that one aspen didn't grow where sage would grow, and I knew that water had (a) reason but to be able to walk through an aspen grove, being like its humid here and there's not a lot of sun, as opposed to getting sunburned out there.

Similarly, Margret brings up the complex interactions that humans may play in ecosystems, by saying,

The definition of the interaction of biotic and abiotic forces kinda how Sandy said, how humans played a huge role … I think that's one of the coolest things I have learned about ecology… science is a verb, and I have learned that its not just something we … observe through a glass, we … are apart of it.
Travis and Margret’s quotes, in conjunction with the pre and posttest answers, show that students were not only articulating what the subject is but starting to put their ideas into broader contexts. By doing so students understood the threshold concepts that allowed them to start to transition from a novice in the field of science or ecology towards expert (Ross, Taylor, Hughes, Whitaker, Mann, Kofod, and Tzioumis, 2010).

The final element of triangulation in the theme definitions was the pre and posttest results of the TOSLS test. These results show that there was no statistically significant growth ($p=0.061$) in science literacy from pre to posttests (see Table 2). A paired sample t-test was completed on the percent of questions answered correctly in the pretest to the percent of questions answered correctly in the posttest. This shows that there was no significant change in science knowledge from the class as whole as tested by the TOSLS assessment (Gormally et al., 2012).

Table 2  
Pair 2 Sample t-test results for TOSLS assessment Pre and Posttest

<table>
<thead>
<tr>
<th>Pair</th>
<th>Pretest TOSLS Mean</th>
<th>Std. Deviation</th>
<th>Posttest TOSLS Mean</th>
<th>Std. Error Mean</th>
<th>T</th>
<th>DF</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-13.286</td>
<td>15.239</td>
<td>15.239</td>
<td>5.760</td>
<td>-2.307</td>
<td>6</td>
<td>0.061*</td>
</tr>
</tbody>
</table>

Notes: This table shows that there was no mean significant change from the number of questions answered correctly from the pre to posttest. See Appendix A for questions asked. 
N= 7 questions  
*p<0.05, two tailed

In total, the pre and posttest definitions of science and ecology show that students became more accurate in their descriptions of these subjects while the audio transcripts provided insight to how students began working through the threshold concepts of science and ecology. However, the TOSLS test results show that there was no statistically significant growth in science literacy from pre to posttest from the class as a whole. Although this is accurate, the
other two data sources show that once students were able to use common terms correctly and have a basic understanding of the key ideas of science and ecology they started making larger connections of ecosystem functions and systems. This is seen further in the next theme.

**Theme 2: Systems Thinking**

The theme of systems thinking was triangulated through data-derived coding of audio transcripts and open-ended questions in the pre and posttests, as well as query analysis of student’s transference papers. Initial codes and keywords that came from the audio transcriptions were clumped and used to define the theme. These included trophic cascades, keystone species, biotic and abiotic systems, nutrient cycling, biodiversity, disturbances and resiliency loops. Once clumped, the theme emerged and was defined as students talking about the connections and levels of ecosystem functions, communities and interconnections of space, time, location and species.

Class discussions were the foundation for this theme, where students used the keywords stated above in the context of processes or scales within an ecosystem. In the final week of the course a discussion focused on students’ land ethics and revealed their thoughts around these interconnections. As Jack explains, even the foundation in which we walk, travel and live on is important:

> I like to think about the natural world as a system of energies and that all living/nonliving things are just things at different states of energy, and those will ebb and flow. As they grow, prosper and die and while I think hierarchy in the natural world should not be a thing it’s not really realistic to like put humans on completely level pegging with everything else. But I do think that it is very important to realize just how
necessary soil and minerals are ah to really all of life I don't think to many people know
the true value of dirt.

Jack came from a science background and these insights reflect this well. While another
student’s revelation and understanding of systems within the environment exposed this. Will
said, “Just understanding about everything is connected and that if you were to destroy this one
area that it could effect something … way higher up.”

Some students began to make parallel connections of systems in their everyday life, such
as Tom who said,

We think about the interactions and that’s incredibly interesting to me I have always been
fascinated by like systems and clocks and moving parts and stuff like that and so, figuring
out ecology was a scientific form of that, ... was really interesting.

Using Tom, Jack and Will as examples for the basis for this theme, they provide insight
in how students’ vocalized their understandings and fascination with systems thinking. This is
emphasized even further through the final transference papers in which students had to draw
connections from their field experience to their lives back home.

Through a process of queries, as explained in the methods section, the researcher was
able to explore where students used the theme systems thinking in their transference papers (see
Figure 3 and 4). These figures specifically show how the initial codes, or keywords, of
“keystone species” and “feedback loops” were used by multiple students and through a variety of
ways.

Students used the term “keystone species” in their transference papers to reflect an
assortment of understandings and ideas, many of whom connected the idea of keystone species
in the course to those that are near home. In Emma’s transference paper she states, “As a
cultural keystone species, because of its contribution to the southeastern region’s forestry industry, the loblolly pine shares many of the same struggles faced by the Whitebark pine in the midst of a drastically warming climate.” This shows that students are making parallel connection to home while extending their knowledge to beyond the scope that was taught.

Figure 3: Keystone Species keyword query in transference papers

Notes: This figure shows us that in the students transference papers they are using the term *keystone species* to articulate an understanding of wolf re-introduction, impact of white-tailed deer in eastern United States and beaver impacts on an ecosystem, to name a few.

In a similar query of “feedback loops,” students make many connections between human resiliency and nature’s natural disturbance cycles (see Figure 4). Jack, who was an avid athlete, compares and contrasts wildland fires to championship running, “Once the fire or championship racing has run its course, it is imperative for the period of reorganization/introduction to have its time and place so that the adaptive cycle can once again complete its loop.” Here he is talking
about recovery of both humans to a disturbance and a forest ecosystem to fire, an interesting and unique perspective.

Figure 4: Resilience loop keyword query in transference papers  
Notes: This figure shows us the various ways in which students used the term feedback or resilience loop in their transference papers. Students have taken this term and applied it to their lives through local disturbances (tornadoes), athletic training or impacts of wildland fires.

These visualizations show the complexity of each term and how varied the interpretations were in the context of the students’ lives at home. Students were able to apply central ecological ideas such as resiliency loops and keystone species to areas such as community development or athletic training.

Following the first two stages of triangulation an analysis of a specific pre and posttest-open ended question occurred. Students were asked to answer the following question in relation to a given illustration, “What message is the illustration below trying to convey? How accurate is
this portrayal and why? Explain” (see Appendix A for illustration). This question provided an
tportunity for students to reflect on trophic cascades and ecosystem functions. The pretest
shows students’ answering this question in terms of basic ecosystem health or function, whereas
in the posttest an emphasis is put on the trickle down effect of apex predators. In Table 3 there is
a comparison of student 1437’s pre and posttest answers to this question (students provided a
unique number to correlate their responses on the pre/posttest, so their identity remained
confidential). This student’s answer was used as a benchmark to represent the class a whole,
who answered similar in nature.

Table 3
**Pre and Posttest question on ecosystem function and trophic cascades.**

<table>
<thead>
<tr>
<th>Student ID</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1437</td>
<td>It is conveying that water supply attracts plants/animals. Also, people scare/harm plants and animals away. It seems accurate that water attracts plants/animals because necessary to life. Also, the cougar scares away the deer because it is prey, this seems accurate.</td>
<td>When cougars are there, they provide nutrients/help to about 23 other species. They are extremely important to ecosystems.</td>
</tr>
</tbody>
</table>

*Notes:* This table shows the pre and posttest answer one student gave to the question: *What message is the illustration below trying to convey? How accurate is this portrayal and why? Explain.* For the pre and posttests students chose a unique number so their answers would remain confidential. In class discussions and transference papers a pseudonym was given to each student by the researcher because she was able to identify who was speaking or writing.

Through triangulation, there was ample evidence to show that students’ ecological and
science literacy was influenced through systems thinking, and their ability to conceptualize this
topic. This influence came in their ability to see the importance of ecosystem functions and
scales from soil and nutrient cycling to the connection of ecological systems to everyday
occurrences such as athletic training.
Theme 3: Human’s Role in the Environment

The theme of human’s role in the environment was triangulated through data-derived coding of audio transcripts, open-ended questions from the posttests, and a query analysis of students’ transference papers. Initial codes and keywords used to define the theme were: preservation, aesthetic-value, recreation, research, re-introduction, inherent value, stewardship, development, conservation and humans as a disturbance. As the theme emerged it became identified by students talking about what role humans should or do have in ecosystems, often pertaining to environmental problems, personal interaction with the environment or their personal land ethic.

There was a progression of how students recognized and verbalized humans’ roles in the environment. It began with students articulating their experience of recreation and moments in wild places. Buck does this by talking about his affinity for hunting and it’s impact on him. He states,

One of my favorite spots to be it is up in a deer stand and in all the heart woods where like nothing has been touched and its just like, you know you see all these animals and its pretty cool and pretty visual. But like also I am still going like to ride my four-wheeler and go out on the boat.

Through this there is an image of being connected with nature in two very different ways, yet both seemingly powerful for him. While Will talks about having a connection to forests where he recreates, “The trails that I run on at … home those are (the) forests (that) I am way more attached to (than) like the millions of other acres of forests in Pennsylvania.” Both of these students express how being out in certain areas creates an affinity for the environment.
Students then transitioned from the role of recreation in the outdoors to the role of humans as a disturbance agent in the natural system. This happened through questioning what role humans should take in the future as well as the basic notion of where humans belong within a trophic cascade structure. Jill points out the scale in which humans have existed on this planet by saying, “We're, if you believe it or not, … a very young species on this planet and maybe these process … are … just naturally reoccurring to reset what we have already done.” Jill questioned how climate change and other natural disturbances may be the environment’s way of resetting itself; whereas, Emma and Margret both talked about the value of humans as stewards or part of the greater community that exists on the planet. Emma said, “whether or not people believe that there is intrinsic value in it or not, its our responsibility to … make sure that it's there and we take the best care of it that we can.” Margret goes on to say,

In short a land ethic changes the role of homo-sapiens from conqueror of the land community to plain member and citizen of it and implies respect for its fellow members and also respect for the community as such…I don't think this is just for us and I like (think it) has the right to continue in its natural state.

These two women were wrestling with the idea of intrinsic value of the environment and where humans stood in that. Another student, Sandy, was more focused on the environmental impacts that humans have had; in saying,

I never would of thought of like holding back fires and the negative affects that can have. And so like its just made me realize how big an effect humans can be like positively and negatively. We can affect the environment more than just pollution.
Although student’s varied in their opinions on humans’ role in the environment, this
dichotomy provided for dynamic discussions. The variability in students’ philosophies was also
emphasized in both the posttests as well as the transference papers.

On the posttests, students were asked to articulate if humans play a role in the
environment, and if so, why and how. After weeks of discussions that focused on social-
ecological systems, as described previously by Margret, Emma and Jill, there was an
overwhelming agreement that humans do play a role in the environment. Yet, students’
reasoning behind how humans are a part of the system varied dramatically, as seen in Table 4.

<table>
<thead>
<tr>
<th>Student ID</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>6490</td>
<td>Yes. I don’t know at this point if we can be considered a part of nature, but we definitely play a role. I think that role is one of disturbances.</td>
</tr>
<tr>
<td>5293</td>
<td>Absolutely. In an essence, we are the stewards of the ecosystems. We wield a lot of power and we could either use this power for good or ill.</td>
</tr>
<tr>
<td>9797</td>
<td>Yes. Humans have almost complete control over almost every ecosystem.</td>
</tr>
<tr>
<td>1694</td>
<td>Yes, we, as a species, affect the earth at a disproportionate rate and scale. There are few, if any, ecosystems that have not been affected by humans in some way.</td>
</tr>
<tr>
<td>2551</td>
<td>Yes, totally. Even in the areas we don’t directly heavily influence, we are affecting every bit of this planet through things like global climate change. We influence ecosystems quite a bit, mostly negatively, not that we can’t change that and do better.</td>
</tr>
<tr>
<td>0607</td>
<td>Yes, thru direct management and indirectly via driving cars/consumption.</td>
</tr>
<tr>
<td>1901</td>
<td>Yes. Every resource we use or consume affects some level of the trophic cascade by depleting or increasing its growth in some way.</td>
</tr>
</tbody>
</table>
Table 4 provides examples of humans’ roles that vary from being a disturbance, to a management system, to stewards of the environment. This wide variety of beliefs was further articulated in the transference papers. Students most notably talked about the similarities and differences between human disturbances and natural disturbances. These comparisons included increased frequency of human disturbances on an ecosystem or the change of a historical disturbance through human intervention, such as wildland fires and logging. A word query was used to find where students talked about “human disturbance” in their transference papers, results are shown in Figure 5.

<table>
<thead>
<tr>
<th>Year</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>Yes, we create a lot of disturbance. We also manage every ecosystem we live in.</td>
</tr>
<tr>
<td>5494</td>
<td>Absolutely. We impact things through development and even by setting aside different areas</td>
</tr>
<tr>
<td>1437</td>
<td>Yes. Social-ecological systems.</td>
</tr>
<tr>
<td>1401</td>
<td>We are both an abiotic and biotic factor. Abiotic because we are just as destructive as a disturbance but biotic because we are also living.</td>
</tr>
</tbody>
</table>

Notes: This table provides insight into how all of the students who answered felt towards humans role in the environment. This also shows the varied responses of the students.
Figure 5: Human Disturbance keyword search in transference papers

Notes: This visualization shows where and in what context students are talking about human disturbance in their transference papers. By doing so, gives light to a variety of contexts in which students wrestled with the idea; from tornadoes to racing and the role of fire.

The students’ progressed throughout the course to talk about their interaction with the landscape around them, from recreation, to their land ethic, to finally their inherent interconnectedness to the environment. Students did not always see eye to eye with each other on what role humans do or do not play in the environment but through triangulation it was shown that they all do believe that humans are intrinsically tied to it. Therefore, students’ understanding of the role of humans in the environment is one more piece of the puzzle when showing their increase in ecological literacy.
Theme 4: Impetus for Change

The theme impetus for change was triangulated through data-derived coding of audio transcripts, statistical analysis of Likert-type questions on the pre and posttest as well as a query analysis of students’ transference papers. Initial codes and keywords that defined the theme included; environmental based economy, policy, education, communication, experiencing places, and passionate leaders. As the theme emerged it was identified by students talking about how to make a difference in some of the issues that face our world such as climate change, development or biodiversity.

After the students talked about the role of humans in the environment, the next step was figuring out the best ways to make a difference in large environmental issues. Most significantly these topics included climate change, fire suppression, biodiversity or human development.

Coding from the audio transcriptions provided insight into how students began to grapple with these complex topics and how to make a difference in them. Through these discussions, students brought in their own perspectives and backgrounds, which included varying majors and future goals. One student, Ben, talked about the different roles of education in creating change;

I would ah agree that education is vital to the process but I also think that there is an initial part, to which is you have to educate yourself to some extent…spread yourself thinking new ways and apply what you learn someplace to new places… but ah I think that bringing what I learned here, to some extent, home is a huge part of expanding as a person, and eventually contributing to the community.

Ben’s insight shows that education has a place in creating change but the impetus is on the person to want to learn. Alternatively, Sandy, who also believed that education was the place to start change, believed that parents play a significant role in educating their children. Where
school provided a learning environment it was only for an abbreviated time and space in the
greater scope of a child’s life. Here she explains, “If you educate the adults they’ll educate the
children then you can't leave parts uneducated ... it needs to be more of the, it needs to be
supported by other people not just their teacher.”

Some students felt that education was where change began, others thought that leadership
and structural change were the answer. Inspired by people who made a difference in
environmental issues, like the Murie family, Erik talked about the role of strong, dedicated
leaders on creating change of larger issues. Here he says,

Yeah I just … think about the influence that one person or small group of people can
have, ... You know like the Muries um and I just think it’s interesting to think of those
people you know sort of just like a spark of inspiration for other people. Um just their
direct action that they(‘re) passion but they also put it to such good use and they helped
you know get the wilderness act enacted and things like that.

As Erik described it, the role of a charismatic leader can have incredible impacts, and
create a ripple effect of vision and action. He later went on to expand on this idea of top-down
structures versus bottom–up. Even though he believed in the spark of leadership and the role they
can have in change, he also articulated, that for substantial change to occur the spark has to come
from within. Where peoples’ values and beliefs are influenced to make a difference, if that
influence comes from a formable leader or elsewhere is unclear. Either way, the comment of
having people emotionally attached (through their personal values and beliefs) is a valuable one.

The personal attachment for seeing change occur can also have its hardships. As Travis
explains, when people become personally invested in an idea it can become difficult to have
productive communication and dialogue. He explains this by stating,
There is such a degree of polarization in every issue, in a way of how people think and people who lead these groups are really impassioned really interpersonal valued people who can't back down, because to back down is to tell themselves that their values are wrong and it so it becomes a mudslinging between hippies and rednecks.

The resolution as he saw it was through looking at structural change, past the waterline model, where people’s emotions don’t have to be rooted in the idea and therefore there would not be as much conflict.

The final idea that students brought up in class discussions to create change was through politics. One student, in particular, was previously jaded by politics and their lack of productivity. He then became impressed by a specific example of a researcher collecting data, going to a legislator and emphasizing the real role of climate change in the arctic. This example provided Jack with a lens for seeing politics as being able to create substantial change resulting in his statement,

The movie last night and coming here … in school all I really do is talk about like environmental problems and how we can fix them through policy and a lot times its just gets really laborious cause we can never really get good solutions to the problems and just really refreshing like come here and see that movie and like see people who like, actually did it they went out did research, got data, and like, went to their legislation and actually got things done ...

We see through the above discussions that students felt strongly about the role of education, policy, dialogue and leadership as being an impetus for change in environmental issues. Using the Likert-type scale from the pre and posttest other ideas emerged as to where students felt change could occur.
As described in the methods section of this paper, the Likert-type questions were clumped via a factor analysis and questions that were found to be significant went through a paired sample t-test (see Table 5). One clumping of questions provides insight into the theme of impetus for change where these three questions saw a significant change from pre to posttest (p<0.05). Students were asked on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree) how they felt about the given subject. This significant change in mean shows an increase in ecological or science literacy via an impetus for creating change. Initially these questions may seem to have very little in common. Yet in the context of the theme, impetus for change, we understand that students began to believe that ecology plays a role in national security, economic growth and their ability to find, read, and understand scientific papers.

Table 5

<table>
<thead>
<tr>
<th>Question 6 (pre/posttest)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>T</th>
<th>DF</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological science offers important contributions to understanding Economic Growth</td>
<td>-.769</td>
<td>1.092</td>
<td>.303</td>
<td>-2.540</td>
<td>12</td>
<td>0.026*</td>
</tr>
<tr>
<td>Question 8 (pre/posttest)</td>
<td>-.923</td>
<td>.954</td>
<td>.265</td>
<td>-3.488</td>
<td>12</td>
<td>0.004*</td>
</tr>
<tr>
<td>Ecological science offers important contribution to understanding National Security.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 18 (pre/posttest)</td>
<td>-1.615</td>
<td>1.502</td>
<td>.417</td>
<td>-3.877</td>
<td>12</td>
<td>0.002*</td>
</tr>
<tr>
<td>I know how to find, read, and analyze a scientific paper on a topic that I am interested in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: This table shows the statistical output of a paired sample t-test for specific Likert-type questions from pre to posttest. Questions were asked on scale of: Strongly Disagree (1) to Strongly Agree (5).
N= 13 students
*p<0.05, two tailed
Thinking back on the data it showed that students recognized that educating people on specific issues is important to be able to create change, incongruence with that, is being able to find, read and analyze information or data properly. Hence the above statistical analysis reemphasizes the role of education in creating change.

As far as the other questions, looking at the student’s transference papers, we see where economic growth and national security play a role. One student, Tom, wrote his paper on the impact of climate change and the role business may have in this issue. In his paper he talked about the role of an environmental market in today’s society, with emphasis on an emission marketplace. In one of the final class periods Tom begins to compare ecosystem functions (abiotic and biotic forces) to business structures (CEO, CFO’s and other competing businesses). Here Tom says,

There are Biotic forces that work which is for a business the internal working, your employees and even that is complex because you've got accounts, clerics, CFO's CIO's CEO's just all down the list ... But then you also have like these abiotic forces which are outside things, outside of your business that you’re not really in control like the market, the time, what other companies are doing that you don't really have control of… like how … business(es) are like a like a faux-ecosystem almost in away.

Because of Tom’s interest in business, and subsequently creation of an environmental market, everyone in the class was exposed to and able to wrestle with the interface of ecology and economics through class discussions. This was reflected by the increase of mean scores from the pretest to posttest question in the Likert-type scale.

The role of ecology in national security can be answered through a similar means. As we saw above in the theme role of humans and the environment, students became acutely aware of
the roles of both human and natural disturbances. In a final transference paper focused on Hurricane Katrina, Ben argued the interconnections of natural disasters and their lasting impact on individuals and a community. As a nation, following Hurricane Katrina, we became deeply aware of the impact that a natural event can have on homeland security issues, ranging from post-disaster relief efforts, immigration, social welfare to inequities of those directly affected by natural disasters (ninth ward as an example from Hurricane Katrina). Below is an excerpt from Ben’s transference paper that emphasizes this interconnectedness of environmental disasters, communities and national security.

Unfortunately, a weak organization infrastructure lead to an overabundance and mismanagement of resources. Although the storm was a natural disaster, the most destructive side of Katrina was unnatural. The poorest in the city lived in the most flood-prone land and were least able to successfully evacuated. Many died waiting for rescue. The journey of Katrina survivors was one of the most massive human migrations in American history (Kukarni et al.). Although evacuees were welcomed with open arms in many cities, there were few opportunities to jump start new lives in an empowered and well-informed manner. While evacuees were seen to be “deserving” of social welfare after the storm, how will we decide how long it “should” take affected individuals to recover? Encouraging resilience is a messy, tedious business that requires intervention backed by thorough research. It verges on evoking the Greek mythological Herculean labors. As of May 2007, more than 30,000 families displaced by Hurricane Katrina were still receiving FEMA rental assistance with another 13,000 in FEMA trailers (Kukarni et al.). With natural disasters such as Katrina are on the rise (Cutter and Emrich 2005), how will we intervene in the future and how we will justify this intervention?
Although this is just one example, it can be tied back directly to class discussions in which all the students and instructors were grappling with the ties of natural disturbances, human disturbances and national security. Through the lens of impetus for change theme, the idea of national security was highly important. Ben made an integral connection between the role of environmental disasters and our own security. By doing so he has opened a door for dialogue and ultimately a potential for change, either for community development or national relief.

In total, students’ ecological literacy and science literacy was influenced in how they found an impetus for change; a change that varied from national security efforts, to economy and education.

**Theme 5: Transference**

The theme transference was triangulated through data-derived coding of audio transcripts and pre and posttests as well as statistical analysis of Likert-type questions. Initial codes and keywords that came from the audio transcriptions were clumped and then used to define the theme, these keywords included; sense of place, future goals, and reflection of personal actions, beliefs and values. The theme was identified by student’s talking about how their field studies experience will either guide life back home or how their home had guided their field studies experience.

The theme of transference can be seen as the apex of the themes. The above four themes were significant building blocks for students to reach a point of being able to connect their individual field studies experience to their lives in a very different (topographic and social) location.

Coding of class discussions was foundational for this theme. In these discussions students, nearly universally, talked about the power of place, and its intrinsic value. They also
discussed how their values and beliefs had changed, and ultimately how they may incorporate ecology and science into their future career goals.

One idea that surfaced many times was the value of place. For many of these students they came from urban settings in the South and had never experienced a place such as the natural setting for this course. By doing so, they reflected on the power that wild areas can have on them. Jill explains this by saying,

> It has been a very enlightening experience. And ah I feel like places like this do remind you that um there are forces out there, they and they maybe Godly or maybe not but they’re bigger than just plain systems and just patterns and there is something that makes everything out here function it not something you can necessarily define and when you look out at those mountains like I do everyday, um you feel something in yourself that can’t be explained by just anything.

Some of the students who were going to school in an urban setting grew up in rural areas. For these students, being in the Western United States, and spending significant time in the field, brought them a new sense of appreciation and respect for their home. Specifically, Emma spoke of her family farm, and it being her favorite place in the world.

Where some students felt that the course provided them transference through valuing place, home or wild areas, other students felt that they were going to incorporate what they had learned into their future career paths. As Ben explains, it doesn’t matter exactly what he does but it will have environmental ties, one way or another.

> I (am) gonna go with my career, I mean maybe law, maybe environmental law, I think that would be awesome. But I don't think it matters where I go I'm gonna go cause I am
going to be passionate about incorporating what we've learned here and the elements of what we've learned here and into my way of thinking whether wherever I go.

As students began to see the role of ecology or science in their future, they also recognized that their values and beliefs had changed while on course. Buck, an avid hunter and fisherman, talked about learning the effects of hunting on the landscape, both positive and negative but more importantly being exposed to people with different beliefs than him on the subject. This insight brought him to this understanding, “knowing these … ideas … it makes me more conscious and respectful of what I am doing and just to … understand the value of each animal and not be wasteful and that kind of thing I am thankful for that.”

Students associated their field course experience to multiple aspects of their lives, from personal values to future career goals. In doing so the course was no longer an isolated event in their lives, but something that had a potential lasting impact.

The students provided more insight in how they would transfer their experience of the field course to back home by answering pre and posttest questions focused on the role of science and ecology in their everyday lives. In the pretests students’ thought of science as being used in their lives through cooking, personal research, exercise routines, health, consumerism, fishing and agriculture. Whereas in the posttest, in addition to healthy living, and research they talked about making observations and asking questions, raising kids, who to be friends with, educating others, voting, and hunting.

An identical question was asked about the role of ecology in student’s daily lives. Here in the pretest students’ answered with water use, environmental footprint, backyard maintenance, living sustainably, camping, clothing choices, consumerism, sustainability, school, activism, how to act around different animals, human impacts on the environment, fishing, farming,
conservation efforts and hiking. While in the posttest students talked about training plans, disturbances, gardening, fishing, international studies, economics, population fluctuations, geographical make-up, reducing impacts, career choices, house and city selection, business planning, raising kids, health, city management, Environmental Justice issues, field research, politics, hunting and farming, erosion and local ecology. Most interesting to note was the shift away from broad environmentalism terms, such as sustainability, conservation, activism, environmental footprint, to terms associated with science, such as research, management, erosion, population fluctuations, and disturbances.

As stated in Chapter 2, a major problem within the scope of ecological literacy is the misunderstandings of ecology in society (McBride et al., 2013). There is a broad misconception of ecology as an activist ideology paralleled with environmentalism. Responses to the pre and posttest questions show that students made a shift of understanding from activism to research in relation to how they may use ecology in their lives.

The Likert-type questions from the pre and posttest also offer insight into students’ understanding of the transference of ideas. The Likert-type questions presented for this theme were analyzed in the same way as the questions for the impetus for change theme, where a factor analysis was performed and then a paired sample t-test for questions that were found to be significant (see Table 6 for results and questions).

Table 6
Paired Sample t-test results for Likert-type questions: Transference

<table>
<thead>
<tr>
<th>Question 13 (pre/posttest)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>T</th>
<th>DF</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often apply ecology in the course of daily life</td>
<td>-1.231</td>
<td>.832</td>
<td>.231</td>
<td>-</td>
<td>12</td>
<td>0.000*</td>
</tr>
<tr>
<td>Question 19 (pre/posttest)</td>
<td>1.231</td>
<td>1.013</td>
<td>.281</td>
<td>4.382</td>
<td>12</td>
<td>0.001*</td>
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</table>
### Science and Ecological Literacy in Undergraduates

**Science is intimidating to me**

<table>
<thead>
<tr>
<th>Question 14 (pre/posttest)</th>
<th>-0.846</th>
<th>0.801</th>
<th>0.222</th>
<th>-</th>
<th>12</th>
<th>0.002*</th>
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</thead>
<tbody>
<tr>
<td>Understanding science is highly beneficial to my future career track in _____</td>
<td>3.811</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 15 (pre/posttest)</th>
<th>-0.846</th>
<th>0.689</th>
<th>0.191</th>
<th>-</th>
<th>12</th>
<th>0.001*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding ecology is highly beneficial to my future career track in _____</td>
<td>4.430</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** This table shows the statistical output of a paired sample t-test for specific Likert-type questions from pre to posttest. Questions were asked on scale of: Strongly Disagree (1) to Strongly Agree (5). 
N = 13 students
*p<0.05, two-tailed
There was significant change in how students saw the role of science and ecology in their lives (p<0.05). They recognized that both, science in general and ecology specifically, can play a part in their future career path as well as daily lives. This was also seen in the audio transcriptions described previously as well as the open-ended questions from the pre and posttests. Over all, students made connections of science and ecology in their lives and were less intimated by science, as seen in the results for question 19 (refer to Table 6).

The influence of transference on the students has been triangulated through audio transcripts, and the pre and posttests (Likert-type questions and open-ended questions). These three data sources validate the ability for students to take what they have learned in the field course and apply it to their values and beliefs, future career goals, and daily lives. Similar field studies programs found comparable results of transference and lasting impacts (Greengrove et al., 2003; Brackney, 2008 and Eves et al., 2007).

Summary

Key findings show that four of the five themes (systems thinking, human’s role in the environment, impetus for change, and transference) were significantly influenced by the field course, via triangulation.

Results described above show that students’ science and ecological literacy grew through their ability to engage in systems thinking, how they perceived humans’ roles in the environment, where and how there should be an impetus for change in environmental issues and how students transfer their knowledge and understandings from the course to the rest of their lives. The definition’s theme was significant in the coding process, though it was unable to be triangulated due to the TOSLS test results.
Chapter 5 Discussion

Introduction

In this final chapter each of the five themes will be discussed further through the lens of Bloom’s taxonomy. Using this taxonomy as the theoretical framework, the themes are able to answer the research question in more depth while also providing implications for this research. The research question that guided this project was: “in what ways does a field studies course (Rocky Mountain Field Ecology) influence ecological and science literacy in undergraduate students?”

Review Bloom’s Taxonomy

As stated in Chapter 3 the Taxonomy of Educational Objectives, commonly known as Bloom’s taxonomy, provides a framework for categorizing educational goals. Educators are able to use this framework to design lessons or units that reflect varying levels of cognitive abilities and skills. If used properly, students begin with knowledge acquisition and move towards critical thinking skills and creative, abstract use of ideas. Below is an elaboration on each theme, showing why students’ ecological and science literacy was influenced in correlation to the stages of Bloom’s taxonomy.

Definitions: Knowledge

At the base level of Bloom’s taxonomy, knowledge provides the foundation for skills and critical thinking to later occur; “by knowledge, we mean that the student can give evidence that he remembers, either by recalling or by recognizing some idea or phenomenon with which he has had experience in the educational process” (Bloom et al., 1956, p.36).
For the Rocky Mountain Field Ecology course, creating a common language of science and ecology was vital for the students to be able to participate fully in class discussions, engage in local issues and ultimately design and implement their own research project. As described in the methods chapter, the first week and good portion of the second were spent learning what would be considered threshold concepts, or those ideas and topics in which someone must understand to be able to move from novice to expert in the field (mentioned in Chapter 2, NRC, 2009; Jordan et al., 2009).

The results of the definition theme provided insight into the students’ ecological literacy and science literacy growth. Students began to articulate the interconnections and scales in which both science and ecology work, and abiotic and biotic forces at play. All of which are threshold concepts identified by NRC (2009; Jordan et al., 2009).

The TOSLS test result, on the other hand, showed that as a whole the class made no significant growth in science literacy from the pre to posttest. This could be contributed to many factors, such as previous knowledge and backgrounds, the focus of this course or the questions specifically used from the test. The course spent significant time talking about ecological concepts while the TOSLS test was specifically created for assessing literacy of classroom biology courses. The results from this test, $p=0.061$, indicate that there still could have been growth in science literacy amongst the students, even if it was not significant. The coding of the audio and open-ended questions emphasizes this growth.

By looking at the definition theme through the lens of Bloom’s taxonomy, it can be recognized that the students’ science and ecological literacy at the knowledge level became solidified. In a traditional introductory science course at a University level students would unlikely move past knowledge acquisition. These classes are based in memorization of ideas and
use “canned labs” to help facilitate understanding, therefore movement towards higher levels of skill and cognitive abilities are not assessed. For Rocky Mountain Field Ecology, the students’ foundational ideas of science and ecology concepts became the basis for the rest of the themes to emerge.

**Systems Thinking: Comprehension**

Systems’ thinking is a threshold concept for both science and ecology. It was also an idea that the students became enthralled with. The notion of how one small piece of the ecosystem could be intrinsically tied to something seemingly far away, or how the role of succession and disturbances created a dynamic process in ecosystem stability, were all areas of discussion. It was also here that the course discussions began to focus on making connections of the natural world to personal lives. One student, Jack, exemplified this by making the connection of similar processes that occur in forest resiliency following a disturbance, such as wildfires, and that which occurs following a championship race within the body.

In Bloom’s taxonomy, they describe comprehension as being the extrapolation of ideas, in saying, “(this) may also involve the making of inferences with respect to implications, consequences, corollaries and effects” (1956, p.90). The translation of ideas and concepts to a subject matter beyond what was taught is the root of systems thinking. Systems thinking, in terms of ecology, helps explain the roles of keystone species, or trophic cascades across a landscape, for example. The transfer of energy through differing levels of producers and consumers may look very different in an alpine ecosystem when compared to a marine system, but once a student recognizes the basic ideas and concepts, they are able to translate them universally. Bloom’s taxonomy recognizes this process as interpreting and extrapolating ideas beyond merely acquiring knowledge of these concepts. The students in Rocky Mountain Field
Ecology showed their comprehension of science and ecological ideas through connecting these concepts to their personal lives as well as larger ecosystem functions and disturbances.

**Research Project: Application**

The students’ weeklong research project parallels the application level of Bloom’s taxonomy. The research project took part during the final week of the course and was a student driven collaborative assignment. Students were broken into groups of 3-4 people where they picked topic areas to focus on, read articles, designed a research question, hypothesized and collected data as well as analyzed and interpreted their results.

The objectives of this assignment were to expose students to scientific research, provide for collaborative student driven efforts and engage in a project-based learning environment, all of which are effective instructional strategies (Dotterer, 2002). Previous research emphasizes the impact of student research projects on the growth of science and ecological literacy in students (Dotterer, 2002; Russell, Hancock, and McCullough, 2007; Lopatto, 2004; Linn et al., 2015).

For Bloom et al., once a student has gained knowledge acquisition, and is able to comprehend ideas, the next step is the application of these concepts (1956). This is explained as, a problem that is stated and identified by the students, who recognize theories or methods in which to solve it, and go through a process of answering the problem (Bloom et al., 1956). This process of knowledge application directly parallels the scientific process that students went through during their research projects.

**Human’s Role in the Environment: Analysis**

In Bloom’s taxonomy, analysis “emphasizes the breakdown of material into its constituent parts and detection of the relationships of the parts and of the way they are
organized” (p. 144, 1956). This was largely seen where students took their values and beliefs and made connections of these to how they perceived humans’ roles in the environment.

By the time students were talking about this theme, discussions were full of rich content examples and connections to their own life. Most inspiring was the large “ah-ha” moments or deep personal transitions they were wrestling with. This was most notable when students were able to have civil discussions about how different they felt about their land ethics, and how their personal values and beliefs played a role in larger environmental issues such as climate change. Interestingly, by the end of the course every student, no matter his or her background, school major, gender or political leaning, believed that humans were intrinsically tied to the environment.

As the course progressed, students’ were able “breakdown” theories and their own beliefs of the role of humans in the environment to elemental and relationship levels. Students’ were able to recognize and analyze human’s impact (both their personal impact as well as society at large) on issues such as biodiversity loss or ecosystem changes. Students were then able to recognize the cause-and-effect relationships of these issues, while breaking them down to elemental levels (such as the role of reintroduction of a apex predator into a system) in correlation to their personal values and beliefs (what role should we play in this?). The ability of the students to breakdown key ecological ideas and environmental issues provided them with the foundation to then understand how to make a difference in these issues, and create change.

Impetus for Change: Synthesis

In studying ecology there is a point in which topics such as climate change, loss of biodiversity, acidification of the oceans, and water scarcity all become relevant conversation topics. This can result in a loss of hope and overall sense of defeat for some. The results for this
theme showed that this was not the case for this field studies class. Instead, students sought an impetus for change.

In the initial week of the course the topic of social-ecological systems was brought up and became increasingly more deliberated by the students and instructors. This timespan of struggling with large topics provided the students an opportunity to move past the “doom and gloom” and towards wanting to see and create change. Through the triangulation of this theme students’ talked about how refreshing it was to have a sense of hope and create specific ideas for where change begins, such as education, economy or dialogue. Also in this theme, students’ transference papers showed how they were able to relate topics of home to those in the course area.

In Bloom’s taxonomy the synthesis stage represents “creative expression” (1956, p.162). Through certain guidelines, or lens’ students are expected to be able to communicate new concepts in the context of other thoughts, experiences or products. As students discussed and wrote about solutions to large ecological issues, they were creating abstract relationships. They pulled elements of their background (school) to the context of their new knowledge (environmental problems) to create solutions. Students’ ability to recognize problems, understand the complex concepts behind why these issues exist and articulate viable solutions shows both creative expression of ideas as well as synthesis of the subject.

**Transference: Evaluation**

The transference theme reflects the highest level of Bloom’s taxonomy, evaluation. In addition to the evaluate level being about creating solutions it is also about placing value on knowledge and creating opinions (Bloom et al., 1956). This is seen through the students reflecting on the value of place (inherent), as well as their future goals (school and career).
SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATES

The results of this theme showed that students were beginning to recognize the value of the field course experience, through either articulating a change in career paths or solidifying previous goals. It was also here that students articulated that even if they did not expect to use the content knowledge directly their new ways of thinking would transfer to wide-reaching aspects of their lives.

The value of what the students learned as well as the lens in which they viewed the world was influenced through this course. Through using a progression of objectives, students were able to build on previous knowledge, their own values and beliefs and ultimately infer these into creating solutions to ecological issues as well as transferring their experience beyond the three weeks of the course. The explanation of these five themes through Bloom’s taxonomy highlights how using educational theory to teach science and ecology can have significant impacts on the students.

Conclusion

This research showed that field studies education is able to influence student’s science and ecological literacy through every level of Bloom’s taxonomy. Students showed knowledge acquisition through definitions, comprehension through systems thinking, application through a research project, analysis through recognizing human’s role in the environment, synthesis through creating an impetus for change and evaluation through transference of understandings.

Undergraduate students must be able and willing to take on the environmental issues that are impacting the world, while also recognizing the role of science and technology in their everyday lives. Undergraduate education must reflect these changes and value students’ comprehension of these subjects. The call for educational reform in science and ecology sought answers for combining theory with practice (D’Avanzo, 2003) while preparing students for
interdisciplinary work beyond their college career. This research showed that by following educational theory such as Bloom’s Taxonomy of Educational Objectives, students’ science and ecological literacy was influenced through field studies education.

**Implications**

This research on field studies education started to answer the call of undergraduate science reform (NRC, 2009). Where there is a need for students to graduate having a basic level of science and ecology understanding. This literacy is in light of the influence of technology and environmental issues in our everyday lives and increasingly into the future (Miller, 2002).

Also, this research provides an example of educational theory in practice for science and ecology undergraduate education. Therefore, this course is an illustration of potential course offerings at a university level, if theory and practice are expected to merge. By teaching science and ecology through educational theory, students are not only leaving the course with knowledge acquisition but also an impetus to create change and see the value of knowledge beyond an institutional setting. These higher order cognitive abilities and skills are what will create active members of society once the student’s graduate.

**Recommendations for Further Study**

Through the process of this research and its findings, extensions and alternative projects were identified. This research, which was a mixed methods design of understanding field studies education, was the first of its kind¹ and because of this, there are many holes that need to be filled.

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¹ A study published in Nature (1963) briefly describes a research project looking at field studies education. This was only a review of the study and the full report could not be found to support or contradict the current research.
The low magnitude of mixed methods research in both the education and science fields creates a need for these fields to cross over more (science to qualitative research and education to quantitative research). By doing this, both fields are able to understand the language that the other is speaking as well as provide data that is well rounded and has greater depth.

An initial step to helping this come to fruition is by creating a quantitative ecological literacy test, similar to the TOSLS test. Second, would be to extend this research to involve other field studies programs and controlled campus based courses. Finally, by redesigning the Likert-type scale used in this research and having it go through a peer review process for validation would help extend the quantitative assessment piece of this study.

In addition to the five themes that were discussed in this paper, a sixth theme was coded but not discussed. This theme was identified as the Learning Environment where students talked in depth about the course itself, both the social-emotional changes that occurred within the students as well as the instructional strategies used. This theme was beyond the scope of this project and the research team did not have data for it to be triangulated. Further research on this data could help define field studies education and the role of these programs on students’ social-emotional status as it pertains to undergraduate education.

Limitations

Limitations to this study include, the researchers’ role within the course and the lack of a control group. The main researcher on this project was an assistant instructor for the course and therefore spent significant time with the students. These interactions, both formal and casual, could have had an impact on the way the data was analyzed. Due to the nature of qualitative analysis the instructor’s personal biases’ or her background may have played a role in the results.
of this research. For the purposes of this study, no control group was used; instead the class was compared against itself to gauge growth.
References


SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATES


SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATES


Nvivo qualitative analysis software (2014); QSR International Pty Ltd. Version 10


Appendix A

Pretest/Posttest Used

Please answer the questions below:

1. In fall of 2014, I will begin my ________________________ (e.g. freshman, sophomore, etc.) year of college.

2. Major: ___________________________ Minor: ___________________________

3. Year of my last science course: ________

4. Year of my last science course with a lab: __________

5. I interact with science on a _____ basis.
   a. daily  b. weekly  c. monthly  d. yearly  e. I very rarely interact with science

6. I interact with ecology on a _____ basis.
   a. daily  b. weekly  c. monthly  d. yearly  e. I very rarely interact with ecology

7. Sex (circle one)  M  F

Please provide detailed comments in regards to the following questions. Please be as thorough as possible.

8. Why did you enroll in this course?

9. What do you expect to learn in this course?

10. What is science, and when and where is it used (please give 3 examples that first come to mind)?

11. What is ecology, and when and where is it used (please give three examples that first come to mind)?

12. What is an ecosystem?

13. From an ecological standpoint, what does it mean to:
   a. Live sustainably
   b. Understand your ecological footprint?
   c. Practice stewardship of the places that you live?
   7. What is climate change?
14. On a scale of 1-5, what is role of humans in influencing climate change (1 = little influence, 5 = great influence)?
Listed below are statements about science, ecology, and human interaction with these disciplines. Please rank each statement by your level of agreement: Strongly Disagree (1), Mildly Disagree (2), Undecided (3), Mildly Agree (4), Strongly Agree (5).

15. The process of science and scientific research offer important contributions to understanding *Human Health*.

16. The process of science and scientific research offer important contributions to understanding *Global Economics*.

17. The process of science and scientific research offer important contributions to understanding *Conservation of Biodiversity*.

18. The process of science and scientific research offer important contributions to understanding *Human Population Growth*.

19. The process of science and scientific research offer important contributions to understanding *How to maintain clean water and air*.

20. Ecological science offers important contributions to understanding *Economic Growth*.

21. Ecological science offers important contributions to understanding *Climate Change*.

22. Ecological science offers important contributions to understanding *National Security*.
23. Ecological science offers important contributions to understanding *How I might live a good, fulfilling life.*

24. Ecosystems are the parts of nature that are free of human influence.

25. Humans are a part of an ecosystem.

26. I often apply science in the course of daily living.

27. I often apply ecology in the course of daily living.

28. Understanding science is highly beneficial to my future career track in __________________ (choose the career track you feel you are most likely to pursue).

29. Understanding ecology is highly beneficial to my future career track in __________________ (choose the career track you feel you are most likely to pursue).

30. I enjoy science classes.

31. I have the ability to understand the science underlying questions that matter to me.

32. I know how to find, read, and analyze a scientific paper on a topic that I am interested in.

33. Science is intimidating to me
34. The health of bee populations affects the quality of my life.

35. Briefly explain your answer to question 34.

36. Creators of the Shake Weight, a moving dumbbell, claim that their product can produce “incredible strength!” Which of the additional information below would provide the strongest evidence supporting the effectiveness of the Shake Weight for increasing muscle strength?

   a. Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week.
   b. Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product.
   c. Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells.
   d. Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial.

37. The most important factor influencing you to categorize a research article as trustworthy science is:

   a. the presence of data or graphs
   b. careful use of statistics
   c. the article was evaluated by unbiased third-party experts
   d. the reputation of the researchers
   e. the publisher of the article

38. Which of the following actions is a valid scientific course of action?

   a. A scientific journal rejects a study because the results provide evidence against a widely accepted model that is generally held to be true by most scientists in that field.
   b. The scientific journal, Science, retracts a published article after other scientists fail to recreate the results of the experiment in a different context.
   c. A senior scientist encourages his graduate student to publish a study containing carefully analyzed, but highly controversial results.
   d. A scientific team chooses not to publish the results of their work because they did not find a statistically significant result.
39. A researcher hypothesizes that immunizations containing traces of mercury do not cause autism in children. Which of the following data provides the strongest test of this hypothesis?
   a. a count of the number of children who were immunized and have autism
   b. yearly screening data on autism symptoms for immunized and non-immunized children from birth to age 12
   c. mean (average) rate of autism for children born in the United States
   d. mean (average) blood mercury concentration in children with autism

40. Background: The following graph appeared in a scientific article about the effects of pesticides on tadpoles in their natural environment.

   ![Graph of Leopard frog tadpole survival](image)

   When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?

   a. The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles.
   b. The Malathion killed the tadpoles, so the beetles had more food and their population increased.
   c. The Malathion killed the beetles, causing fewer tadpoles to be eaten.
   d. The Malathion killed the beetles, causing the tadpole population to prey on each other.

41. Two studies estimate the mean caffeine content of an energy drink. Each study uses the same test on a random sample of the energy drink. Study 1 uses 25 bottles, and study 2 uses 100 bottles. Which statement is true?
   a. The estimate of the actual mean caffeine content from each study will be equally uncertain.
   b. The uncertainty in the estimate of the actual mean caffeine content will be smaller in study 1 than in study 2.
   c. The uncertainty in the estimate of the actual mean caffeine content will be larger in study 1 than
in study 2.
d. None of the above

42. Researchers found that chronically stressed individuals have significantly higher blood pressure compared to individuals with little stress. Which graph would be most appropriate for displaying the mean (average) blood pressure scores for high-stress and low-stress groups of people?

43. What message is the illustration below trying to convey? How accurate is this portrayal and why? Explain.

44. List three ways you most likely to use science in your life.
45. List three ways you are most likely to use ecology in your life.
Appendix B

Course Syllabus

**Course Title:** Rocky Mountain Ecology Field Research  
**Instructors:**  
**Graduate Teaching Assistants:**  
**Course Dates:** June 1-June 26, 2014  
**Semester Credits:** 4  
**Contact Hours:** 165+  
**Foundation Credit:** F7 and F11  
**Accommodations:**  
- 22-23 nights at Kelly Camp, rustic log cabin setting  
- 3 nights camping in Yellowstone  

**COURSE OVERVIEW**  
This field-based course is focused on the ecology of the Greater Yellowstone Ecosystem (GYE). Topics include: the influence of large-scale, regional abiotic processes (such as geology, climate and water cycling) on ecological patterns and processes; community composition and interactions among organisms; community dynamics and patterns of succession; natural disturbance regimes (such as fire and disease); trophic interactions among organisms (including the role of apex consumers); social-ecological systems; human influence and management; and identification/taxonomy of plants, mammals and birds. Students will become familiar with basic processes of field inquiry, project design, research techniques and data collection. Examples and papers illustrating how regional research influences topics covered in this course will be presented throughout. The course will connect students with regional scientists and land managers, as well as other programming areas of the GYE, to empower students as they consider future professional development opportunities.

**EDUCATIONAL OBJECTIVES**  
1. Encounter the discipline of ecology – as defined by the interaction of biotic and abiotic factors across multiple scales in space and time, from geologic, elemental and climactic drivers, to floral and faunal interactions and adaptations, to human influence and management.  
2. Learn to identify and conceptualize key ecological patterns and processes that define the GYE, such as spatial distribution of vegetative communities, disturbance regimes, and trophic cascades.  
3. Explore composition of and interrelationships between organisms within and among dominant vegetation community types (sagebrush, aspen, conifer and riparian), topics include niches, diversity, competition, resource partitioning, predation, herbivory, symbioses, facilitation, succession and disturbance.  
4. Develop taxonomic and field identification skills in ornithology, mammalogy, and botany.  
5. Understand how human influence and management has and will continue to shape the GYE  
6. Practice outdoor skills and managing risk in the Rocky Mountains.  
7. Practice teamwork, listening, leadership, and cooperation by working in groups and utilizing the aptitudes and experience of all group members to complete projects.  
8. Engage scientific papers to understand how the scientific method and ongoing regional research projects add to the ecological content of this course.  
9. Gain exposure to different types of research through collaboration with ecologists working on long-term scientific projects in the GYE. *Bird Banding*
10. Practice the process of science by asking questions about ecological interactions in the GYE and designing original research to address these questions.

11. Develop and investigate researchable field-based scientific questions

12. Develop and implement project design, including field-based methodologies and research techniques for collection of scientific data —> CREATIVITY

13. Learn how to manage and analyze data

14. Develop an understanding of the purpose and role of statistics in ecological field research, including differentiation between biological significance and statistical significance

15. Workshop with instructors and peers to gain experience extrapolating from data, discussing significance and limitations of results, and drawing conclusions

16. Present the findings of scientific research to peers and research professionals

17. Apply skills and experience gained through this course to develop a scientific research project proposal to answer an ecological question in Medicine Lake, or a nearby ecosystem

18. Develop science and ecological literacy skills applicable throughout life

READINGS AND EQUIPMENT

There are no required texts for this course, but the following field guides are optional for birds and plants:

- *Plants of the Rocky Mountains*: Kershaw, Pojar, and MacKinnon

**Assigned Readings**

Once you arrive at Medicine Lake, you will receive photocopies of the assigned readings listed in course schedule below. We will discuss these readings throughout the course at varying levels of depth. Don’t worry, you will not have to read all of these in great detail. Some of these readings you will be asked to read carefully, others we will work through together, divide and conquer, or read aloud.

**Optional Background Reading**

The following books are recommended as pre-trip reading:

- *Mountains and Plains: The Ecology of Wyoming Landscapes*, by Dennis H. Knight. An excellent book covering the vegetative communities of WY (out of print difficult to find)
- *A Field Guide to the Hoofed Mammals of Jackson Hole*, by J. Brad Stelfox and Lynne Lawrence

**Student Equipment Required**

Field notebooks, field clothes, sit pad, binoculars, hand lens. You will receive a detailed equipment list related to traveling and living in the Rocky Mountain.

**Expectations and Assessment**

This is a letter grade course. Rubrics will be provided for all assignments. Grading is based on the percentile scale below, and grade point credit will be awarded on a 4.0 scale, see table below. Daily attendance is mandatory per policy. Students are expected to complete work in a timely and professional manner. The equivalent of one letter grade per day will be deducted for late assignments.

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COURSE SCHEDULE
*Instructors reserve the right to change course material and schedule to enhance the learning experience for Rhodes students. Please see all material in this schedule as flexible.

Week #1

Sunday, June 1 - Arrivals
• Arrival to [Instructor's name]
• Tour of campus
• Gear Checkout

Monday, June 2 – Welcome and Logistics
• Morning-Afternoon: Welcome, introductions, and syllabus overview, Wilderness 101 and Risk management – living and learning in the GYE; wildlife training
• Evening: Reading the GYE landscape – elemental/ecological patterns and processes, biotic and abiotic components, dominant vegetative communities, adaption to a harsh climate, intro to geologic processes of the GYE human-managed landscapes?

Tuesday, June 3 – Rock and Ice: Elemental and Abiotic Processes Drive Life in the GYE
• Morning: Sedimentary geology and water: shaping our dynamic landscape – erosion, deposition, soil, and fine scale vegetation patterns, intro to glaciers and outwash
• Afternoon: Metamorphic and glacial geology, faulting
• Evening: Rest, read, and settle in

Wednesday, June 4 – Sage-Aspen Community Ecology
• Morning: Exploring communities, ecotones, adaptations, and diversity using birds as guides
• Midday: Sagebrush ecology, soils, diversity, competition, floral adaptations, wildflower identification
• Afternoon: Aspen ecology; Aspen-conifer succession
• Evening: Social-ecological Systems

Thursday, June 5 – Conifer Ecology, Abiotic and Biotic Drivers of Disturbance
• Morning: Conifer ecology, fire ecology, disease ecology
• Early Afternoon: Fire ecology
• Late Afternoon: Reading a scientific paper
• Evening: Murie Video


Friday, June 6 – Riparian Ecology, Ecological Complexity, the Concept of Scale, and Human Dimensions
• Early-morning: Bird banding
• Morning-afternoon: Riparian habitat and species diversity, reading a scientific, trophic cascades, the importance of riparian habitat, vegetative structure, keystone species, apex consumers, and human influence
• Evening: YNP Wolf Video

SCIENCE AND ECOLOGICAL LITERACY IN UNDERGRADUATES


Reading 6: Smith and Wachob. 2006. Trends associated with residential development in riparian breeding bird habitat along the Snake River in Jackson Hole, WY, USA: implications for conservation planning. *Biological Conservation* 128: 431-446

Saturday, June 7 – Jackson and Yellowstone Prep  
- Morning: Natural boundaries, human boundaries: how have humans shaped and interpreted this ecosystem? (*National Museum of Wildlife Art, Elk Refuge*)
- Late morning through midday: Lunch and a little free time in Jackson
- Late afternoon: Personal items packed for Yellowstone
- Evening: R&R (Farmers Market)

Week #2

Sunday, June 8 – The Yellowstone GeoEcosystem
**Accommodations:** Tower or Mammoth Campground, Yellowstone National Park
- Early morning: Depart for Yellowstone
- Morning-Afternoon: Introduction to the Yellowstone geosystem and super-volcano (*Old Faithful*), hydrothermal geology & bacterial community ecology (*Grand Prismatic Overlook*), Norris Geyser Basin
- Late Afternoon/Evening: Set up camp

Monday, June 9 – Trophic Cascades in Yellowstone: Apex Consumers Shape Ecosystems
- Wildlife viewing
- The reintroduction of wolves to the GYE – Readings from *Decade of the Wolf*

Tuesday, June 10 – Trophic Cascades in Yellowstone: Apex Consumers Shape Ecosystems
- Wildlife viewing, wolf stories with Rick MacIntyre, Interpretive Biologist for the Yellowstone Wolf Project
- Predator-prey ecology, wood webs, trophic cascades, the importance of apex consumers for biodiversity and ecosystem health, scientific paper each-one-teach-one


**Reading 2:** Ripple and Beschta. 2004. Wolves and the ecology of fear: can predation risk structure ecosystems? *Bioscience* 54(8): 755-766

**Reading 3:** Ripple and Beschta. 2012. Trophic cascades in Yellowstone: the first 15 years after wolf reintroduction. *Biological Conservation* 145: 205-213


**Reading 5:** Brodie et al. 2012. Climate change intensification of herbivore impacts on tree recruitment. *Proceedings of the Royal Society of Biological Sciences* 279: 1366-1370

Wednesday, June 11 – Yellowstone in Context: the History and Future of Conservation on a Changing Planet
**Accommodations:** Return to TSS
- Wildlife viewing, discuss history and cultural/political symbolism and challenges of wolves, wilderness, and climate change
- More Yellowstone geology, landscapes, ecology, critters, and climate
- Evening: return to Teton Science School, unload and clean supplies


Thursday, June 12 – Introduce Transference Paper and Exam Prep
- Morning: Workshop – transference paper workshop
- Afternoon: Exam study session and course synthesis
- Evening: Study Time

Friday, June 13 – Exam and Synthesis
- Morning: Mid-term exam
- Late-morning through Midday: Prep for synthesis presentations
- Mid-afternoon: Review exam, synthesis hike, social-ecological systems
- Evening: DamNation film in Jackson

Saturday, June 14 – Explore and Relax in Grand Teton
- Morning – Coulter Bay
- Evening - TBD

Week #3

- Morning: Review of the scientific method, hypothesis testing, formalizing testable questions, brainstorm project ideas. Leadership Exercise
- Afternoon: Introduction to research proposal development, assign research groups
- Late-afternoon - evening workshop: Research proposal development – topic, hypothesis, question, research design (break for dinner)

Monday, June 16 – Statistical Analyses, Research Proposal Presentations, and Field Preparation
- Morning: Principles of data collection, intro to statistical analysis – use of Excel, R software, and/or other statistical packages
- Mid-Morning Workshop: Research proposal development - research design and statistical analysis
- Lunch: Present research proposals to class, student and instructor feedback
- Afternoon: Research proposal refinement, gather field gear, pilot test methods, and review field logistics
- Evening: Reading/work on research projects

Tuesday, June 17 – Research Project Implementation
- Morning and afternoon: Field research project data collection, data organization, set up for analysis
- Evening: Reading/work on research projects

Wednesday, June 18 – Shadow Field Ecologists and Research Project Implementation
- Morning and afternoon: Field research project data collection, data organization, set up for analysis
- Evening: Reading/work on research projects

Thursday, June 19 – Research Project Implementation, attend Research Seminar
- Morning and afternoon: Field research project data collection, data organization, set up for analysis
- Late afternoon - evening: Tour, BBQ, and attend research seminar at AMK ranch

Friday, June 20 – Research Project Implementation and Develop a Scientific Presentation
- Morning - afternoon: Field research project data collection, data organization, set up for analysis (field and TSS)
- Evening: Preparing and executing a professional scientific research presentation (TSS)
Saturday, June 21 – Data Analysis, Research Wrap-up, Presentation Preparation
- Morning – evening: Data analysis, research wrap-up, presentation prep

Sunday, June 22 – Fun with Grads
- Morning-afternoon – TNP, Colter Bay
- Evening: Work on Projects

Monday, June 23 – Shadow Researcher(s) and Presentations
- Morning-Afternoon – Shadow ecologists doing research in the GYE
- Evening: Group scientific research presentations, open to the public

Tuesday, June 24 – Social-ecological Systems
- Morning-Afternoon: Meet with stakeholders in GYE
- Evening: Discuss SES

Wednesday, June 25 – Course Reflection, Synthesis, and Celebration
- Morning through midday: Group reflection, synthesis discussion, assessments
- Mid-afternoon: Hands to work and course evaluations
- Evening: Campfire celebration

Thursday, June 26 – Depart TSS
- Clean dorms
- Departures

ASSESSMENT:

Mid-course exam (Friday, June 13) 20%
Goal: Promote understanding of course material and stimulate critical thinking skills

Quality of participation in field exercises and discussions 20%
Goal: Stimulate interest in field studies and provide experience in collecting field data
Assessment criteria:
- Was the student present and engaged in field work?
- Did the student contribute to thorough and timely completion of the field work?
- Does the student demonstrate evidence of completing required readings?
- Does the student ask thoughtful questions?
- Does the student freely discuss pertinent issues and share their own perspectives?

Course journal 20%
Goal: Provide structure for recording field observations throughout the course
Assessment criteria:
- Does the student articulate essential understandings of the ecology of the GYE?
- Are both visual and written descriptions used to elaborate understandings?
- Does student include thoughtful reflection on their experience and what they are learning?

Oral research project presentation (M. evening, June 23) 20%
Goal: To creatively present learning from the Rocky Mountain Ecology course
Assessment criteria:
- Are key course concepts included?
- Clarity of presentations (clear, logical, and well organized)
- Do students fully understand goals/objectives of their research projects?
- Use of time and ability to deal with the questions from the audience.
**Product:** 15 minute oral presentation

**Paper on transfer of course concepts and research objectives to a familiar place (Due July 12) 20%**

**Goal:** To connect concepts learned and the scientific method to a familiar place at home

- Students will apply a key concept learned during their Rocky Mountain Ecology course and research a relevant topic in the Tennessee bio-region of the United States or another place with significance to the student.
- Students will prepare a research proposal to answer a scientific question of interest related to their topic.
- Example: Geology determines biology. Is it possible to research the impacts of sedimentation and how it affects riparian ecosystems in Tennessee? What is understood? What questions are left unanswered? What are some solutions or possible areas to be researched in the future? How would I go about trying to answer a specific question (scientifically) about the effect of sedimentation on a riparian area in Tennessee?

**Assessment criteria:**

Does student demonstrate connections to previous or future learning at Rhode?  
Was an ecological connection between the GYE and other location articulated?  
Was the writing clear, logical, and well organized?  
Does the research proposal outline a question that can be answered using the scientific method? Are all steps of the sci. method addressed?  
Is background information relevant and thorough?

**Product:** 4+ page paper, single spaced text, 12 pt. font. Be succinct and to the point.